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Use of Anesthesia Induction Rooms Can Increase the Number of Urgent Orthopedic Cases Completed within 7 Hours

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Background: **Mean turnover times and the time spent in the operating room (OR) can be reduced by concurrent induction of anesthesia. Previous studies of anesthesia induction outside the OR have concentrated either on anesthesia-controlled time or turnover time. The goal of this study was to investigate the impact of an induction room model on the whole surgical process, its phases and delays between the phases, and the number of cases performed during the 7-h working day.**

Methods: **A prospective analysis of OR times was conducted for 5 weeks with the traditional induction-in-the-OR model followed by 4 weeks with a new model: A team of two nurses and one anesthesiologist was added to one OR to perform parallel anesthesia induction in a separate induction room. The durations of phases of surgical process, number of completed cases between 7:45 AM and 3:00 PM, and daily raw utilization of the OR were assessed. Results were compared to those measured before the intervention.**

Results: **The mean nonoperative time was reduced by 45.6%, whereas surgery time remained unchanged. The time savings contributed to the concurrent anesthesia induction and the cut down in delays between the phases. The new model allowed one additional case to be performed during the 7-h working day.**

Conclusions: **Anesthesia induction outside the OR can increase the number of surgical cases performed during a regular workday.**

CONCURRENT induction of anesthesia has been shown to decrease mean turnover times[1] and the time spent in the operating room (OR). This practice has been adopted in many operating units in Europe, where anesthesia induction is routinely performed parallel with the preceding procedure. Eighty-one percent of the ORs in Switzerland and 94% of the ORs in the United Kingdom have separate induction rooms, whereas in the United States and in most Scandinavian countries, ORs are often built without induction rooms.[2,3] An induction room is considered to provide a calm environment for the patient and the anesthesiologist and to reduce anxiety among patients.[4]

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Williams *et al.*[5] compared the anesthesia-controlled time (ACT) values based on anesthesia techniques and locations where they were applied. ACT consists of OR entry until surgical preparation begins plus the end of surgical procedure until OR exit. Regional anesthesia performed in the induction room was associated with the lowest ACT compared with general or combined general–regional anesthesia in the OR. Also, use of a "block room" to perform regional anesthesia before the operation significantly reduced the preprocedure OR time when compared with the regional anesthesia performed in the OR.[6]

Previous studies have concentrated either on ACT or turnover time. We focused on the whole surgical process and its phases and delays between the phases. Our goal was to investigate the impact of moving the anesthesia induction out of the OR on the throughput times of the surgical process of the OR and on the completed cases between 7:45 AM and 3:00 PM.

Materials and Methods

This prospective study was approved by the Ethics Committee, Department of Surgery, Hospital District of Helsinki and Uusimaa, Finland. The study was conducted in the Orthopedic and Trauma Operating Unit of Töölö Hospital, Helsinki University Central Hospital, Helsinki, Finland. The unit consists of four ORs, two of which are allocated for urgent and emergent trauma cases only. One of these ORs is open 24 h a day, and one is staffed from 7:45 AM to 10:00 PM. An average of 5,000 urgent and emergent procedures are performed yearly.

For the induction room model, the human resources of the unit were rearranged to allow two nurses and one anesthesiologist to perform anesthesia inductions in the induction room of one OR concurrently with the preceding procedure. After the rearrangement, the calculated addition of resources in that room was 1.25 nurses and 0.25 anesthesiologists for that specific OR. The total resources of the both models are illustrated on table 1. The 0.25 value represents one staff person allocated to

Table 1. Numbers of Staff Members in the Two Models

Staff Members	Traditional Model	Induction Model
Anesthesia nurses	1.25	2
Anesthesiologists	1	1.25
Perioperative nurses	2.5	3
Surgeons	1	1
Total	5.75	7.25

four ORs, and the 0.5 value represents one person for two ORs.

The workflow of the induction team members is as follows: By the end of the first case of the day, the induction team— consisting of one anesthesiologist, one anesthesia nurse, and one circulating nurse—will call for the next patient and perform anesthesia induction (fig. 1). Should the induction of patient 2 and the emergence of patient 1 overlap, the anesthesiologist will ask a colleague to help with the emergence. Otherwise, he or she will take care of all cases in that room. The anesthesia nurses in our country are allowed to monitor the patient and maintain anesthesia alone in the OR but are not allowed to perform induction or emergence. When room cleanup is finished, the induction team will follow patient 2 into the OR and proceed with the positioning, the surgical preparation, and the procedure.

The nurses from case 1 will take their patient to the postanesthesia care unit and sign over. One of the nurses will have a break, two others will call for patient 3, anesthesia will be started, and so on. No extra personnel are needed to give the team members breaks during the day.

Operating room times of that room were manually recorded on a standardized form (appendix) for a 5-week baseline period before and for 4 weeks after the implementation of the induction room model. Consecutive procedures performed in that room Monday to Friday from 7:45 AM to 3:00 PM were included regardless of the type of procedure or the type of anesthesia. The monthly overtime hours of the nursing personnel were obtained from the hospital administration's information system.

The mean surgery time (from incision to closure), nonoperative time, sum of case time and turnover time, and daily raw utilization of the OR were assessed. In addition, the 90% and 10% percentile values of surgery time were calculated for both periods. The daily number

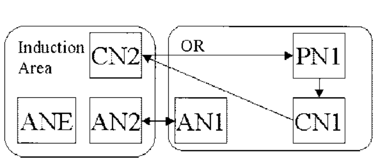

Fig. 1. Workflow of the staff in the study operating room (OR). AN = anesthesia nurse; ANE = anesthesiologist; CN = circulating nurse; PN = perioperative nurse.

of completed cases between 7:45 AM and 3:00 PM was assessed.

Nonoperative time was defined as the time starting when surgical closure was finished and ending by the incision of the next patient. The sum of case time and turnover time was defined as the time starting when one patient entered an OR and ending when the next patient entered the OR. Daily raw utilization was the percent of time that patients were in the room between 7:45 AM and 3:00 PM (American Association of Clinical Directors).[7]

The value-adding times and delays of the OR process were researched using detailed measurements. Value-adding times included the following intervals: from start of anesthesia to patient ready for surgery (anesthesia preparation and surgical preparation), surgery time, from surgery finish to patient out of room, and room cleanup. Delays between phases were defined as idle times between the value-adding phases (such as patient arrived late, surgeon arrived late).

The theoretical labor cost-efficiency was analyzed by the equation (mean sum of case time + turnover time) × (average cost of direct resources/h) using the actual values of both periods. The labor costs were calculated using the average salaries of the personnel in year 2002. The induction room is equipped with a similar kind of anesthesia workstation as the OR. The cost of the induction room was not included because the hospital was originally built with induction rooms.

The measures are presented as mean ± SD. The cumulative distributions of surgery time as well as 10% and 90% values of surgery times are presented. The normality of data were tested using the Anderson–Darling test. The differences between models were analyzed by independent-samples *t* test or Mann–Whitney U test depending on the normality of the distribution. A P value of less than 0.05 was considered statistically significant. In the comparisons between models, the 95% confidence intervals were calculated.

Results

The types of anesthesia and surgical procedures are listed in table 2.

The values of the measurements are shown in table 3. The mean surgery time was 9 min shorter with the induction model (nonsignificant). The SDs of surgery times were substantial in both models because of the variation of the procedure types and surgeons. The cumulative distribution of surgery times is illustrated in figure 2.

The reduction in nonoperative time was 45.6% (95% confidence interval, −34.7 to −56.5%; $P < 0.001$). In addition, the SD of nonoperative time was significantly smaller. The daily raw utilization of the OR increased by 8.9%. With the induction room model, it was possible to perform one additional case during the 7-h block.

Table 2. Numbers of Anesthesia Types and Procedure Types

	Traditional Model	Induction Model
Type of anesthesia		
General anesthesia	33	36
Spinal block	19	33
Brachial block	4	6
Bier block	1	2
Total	57	77
Type of procedure		
Hip fracture	12	13
Foot or ankle fracture	9	15
Hand surgery	11	14
Arm or forearm fracture	15	18
Miscellaneous	10	17
Total	57	77

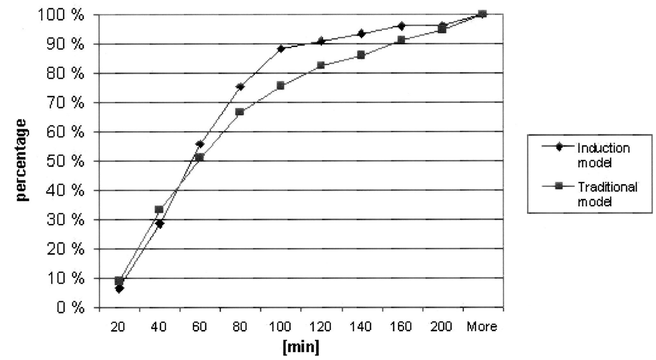

Fig. 2. Cumulative distribution of surgery times in the different models. The 90% and 10% intervals are 111 and 25 min in the induction model and 156 and 23 min in the traditional model, respectively.

There was no statistically significant decrease in the duration of value-adding intervals, except for room cleanup, whereas all the delays between the intervals were reduced. The value-adding intervals and delays are illustrated in figure 3.

Monthly overtime hours of the operating unit decreased from 196 h to 190 h (*i.e.*, did not increase). The theoretical labor cost-efficiency analysis showed an improvement in cost-efficiency of 16%.

Discussion

With the induction room model, the reduction of the nonoperative time of the OR was substantial enough to allow one additional case to be performed during a relatively short, 7-h working day. Dexter *et al.* [8] demonstrated that reductions in ACT alone did not allow extra cases of the same procedure to be scheduled reliably, unless all case times in that room were less than 45 min. In our circumstance, the extra cases were not of the same procedures, and all were urgent cases (*i.e.*, unscheduled) available in the hospital to start earlier in the workday if the intervention reduced the cycle time (case time + turnover time).

In this study, approximately half of the time savings contributed to the concurrent anesthesia induction, and the rest was gained by the cut down in delays between the phases (fig. 3). This may explain the fact that the decrease in nonoperative time in this study was greater than that in previous studies.[1,5,6]

The immediate location of the induction room may partly contribute to the cut down of the idle time. In our institution, room setup is done while the patient is already in the room, and turnover time basically consists of sign-over of the patient to the recovery room and transporting the next patient in. Meanwhile, the room is cleaned up. In the induction room model, the next patient was anesthetized and ready to be wheeled in when room cleanup was finished. This additional pressure may also explain why room cleanup time was reduced in this study.

Because both observation periods were publicly declared, there is the risk of the Hawthorne effect, *i.e.*, people behaving differently when being observed. However, OR times are regularly and openly monitored in our institution as a quality control measure, and it is our understanding that our staff is used to being monitored. We believe that, even if the Hawthorne effect occurred, it was similar in both models.

The fact that there were more spinal and brachial blocks in the induction room group could have some impact on the reduction of the nonoperative time, as demonstrated by Williams *et al.*,[5] because those patients do not need to emerge from anesthesia. However, there was no statistically significant difference in this study between the two models in the mean duration of the interval between the end of surgery and the patient being ready for transport (fig. 3). Hence, it did not affect the results of the study.

In the study by Sokolovic *et al.*,[1] the cost for two extra staff members for anesthesia induction was assessed.

Table 3. Durations of Phases in the Study Operating Room

Metrics	Traditional Model (n = 57 Cases)	Induction Model (n = 77 Cases)	*P* Value
Surgery time, min	73 ± 51	64 ± 43	0.16*
Nonoperative time, min	90 ± 25	49 ± 9	< 0.001
Sum of case time + turnover time, min	156 ± 70	108 ± 36	< 0.001
Daily raw utilization, %	83.6 ± 9.5	91.0 ± 5.6	< 0.001
Completed cases before 3:00 PM per day	2.3 ± 0.5	3.3 ± 1.0	< 0.01*

Data are presented as mean ± SD.

* Nonparametric.

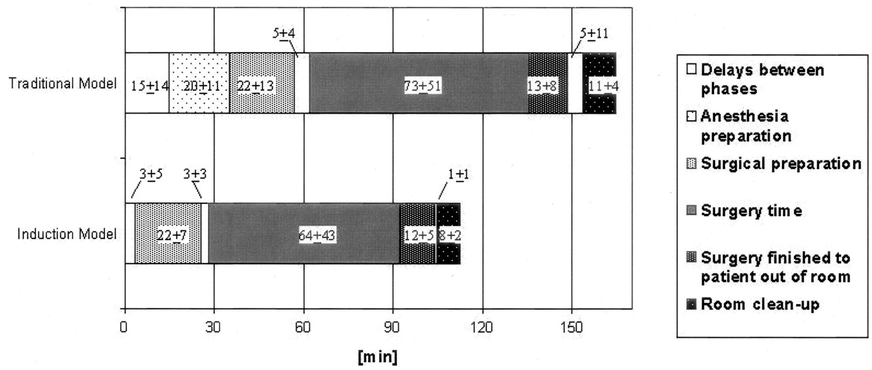

Fig. 3. Phases and delays of the surgery process in the operating room; traditional and induction models. Data are presented as mean ± SD.

The resulting financial benefits outweighed the expenditure. However, the overtime of the staff increased sixfold. Also, the mean case duration during study conditions was significantly shorter compared with that during control conditions.[1] Which part of the benefits contributed to the parallel anesthesia induction and which contributed to the operations performed during overtime was not explained in that study.[1] In our study, monthly overtime hours of the whole surgical unit did not increase after the implementation of the induction room model. Also, there was no statistically significant difference in the duration of surgery time between the groups.

In previous studies, the definition of efficiency varies. Operations per unit of time,[1] as well as OR times[9] and wasted OR time,[10] and the sum of underutilized and overutilized time[11] have been used as measures for efficiency. In our study, the increased raw utilization (from 84 to 91%) together with the decreased nonoperative time and the fact that more cases could be performed during the day without significant increase in staffing strongly suggests that the efficiency of the OR process was increased. In addition, our theoretical analysis indicates that during the study, labor cost-efficiency was better in the induction room model.

The reduced nonoperative time does not lead to valuable improvements if the staff and the number of ORs in use remains the same. In our unit, one OR is staffed 24 h a day, and one is staffed until 10:00 PM. Another team of three nurses stays late if a third OR is needed after 3:00 PM or a second one is needed after 10:00 PM. According to Abouleish *et al.*,[12] the cost of an overtime hour can equal 1.75 times the cost of a regularly scheduled hour, in which an increment of 0.25 reflects the indirect costs of employee dissatisfaction and resignation, resulting in recruitment costs. Our goal is—by decreasing the nonoperative time with several induction rooms in use instead of just one—to decrease the number of staffed ORs after 3:00 PM. This would cause savings in labor costs as well as improved work satisfaction.

The cost of the anesthesia workstation is approximately 50,000 euros. According to our estimations, the yearly savings potential is greater than that if the staff is reallocated as described above.

The workflow of our induction team was developed to ensure the continuous care of the patient: The same team takes care of the patient throughout the process. However, a separate team that would take care of only anesthesia inductions could serve several ORs and would most likely be more cost-efficient. That kind of system is more challenging from OR managers' point of view. More studies are needed to compare the different workflow patterns.

Scheduling operations according to predicted duration of the case can further augment the benefits of parallel anesthesia induction. The double-queue scheduling solution as described by Karvonen *et al.* [13]—one queue for short procedures and one for longer ones—can be used to maximize the benefits of decreased nonoperative time. Scheduling short cases in some of the ORs with a staffed induction room and longer cases in another without an induction room could be a solution for units with many ORs.

Previous studies have focused on ACT and turnover time. Our opinion is that changes in nonoperative time best reflect the improvement of the process itself. The nonoperative time includes all the phases and delays in between and therefore offers a better metric for estimating the performance of the whole surgical process.

The implication of the reduced nonoperative time with the induction model is to be able to perform more cases during the workday, to increase efficiency, to cut down overtime work, or to shorten patient waiting times. More studies will be needed to investigate in terms of efficiency which other phases of the surgical process could be performed outside the OR.

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References

1. Sokolovic E, Biro P, Wyss P, Werthemann C, Haller U, Spahn D, Szucs T: Impact of the reduction of anaesthesia turnover time on operating room efficiency. Eur J Anaesth 2002; 19:560–3

2. Sieber TJ, Leibundgut DL: Operating room management and strategies in Switzerland: Results of a survey. Eur J Anaesth 2002; 19: 415–23

3. Bromhead HJ, Jones NA: The use of anaesthetic rooms for induction of anaesthesia: A postal survey of current practice and attitudes in Great Britain and Northern Ireland. Anaesthesia 2002; 57:850–4

4. O'Connor D, Dopson A, Smith S: Inducing anaesthesia in the operating theatre: Staff and patient opinions. Anaesthesia 2003; 9:912–3

5. Williams BA, Kentor ML, Williams JP, Figallo CM, Sigl JC, Anders JW, Bear TC, Tullock WC, Bennett CH, Harner CD, Fu FH: Effects of regional and general anesthesia on anesthesia-controlled time. ANESTHESIOLOGY 2000; 93:529–38

6. Armstrong PJ, Cherry RA: Brachial plexus anesthesia compared to general anesthesia when block room is available. Can J Anesth 2004; 51:41–4

7. Donham RT, Mazzei WJ, Jones RL: Glossary of times used for scheduling and monitoring of diagnostic and therapeutic procedures. Am J Anesth 1996; 23:5–9

8. Dexter F, Coffin S, Tinker J: Decreases in anesthesia-controlled time cannot permit one additional surgical operation to be reliably scheduled during a workday. Anesth Analg 1995; 81:1263–8

9. Overdyk FJ, Harvey SC, Fishman RL, Shippey F: Successful strategies for improving operating room efficiency at academic institutions. Anesth Analg 1998; 86:896–906

10. Weinbroum AA, Ekstein P, Ezri T: Efficiency of the operating room suite. Am J Surg 2003; 185:244–50

11. Strum DP, Vargas LG, May JH, Bashein G: Surgical suite utilization and capacity planning: A minimal cost analysis model. J Med Syst 1997; 21:309–22

12. Abouleish AE, Dexter F, Epstein RH, Lubarsky DA, Whitten CW, Prough DS: Labor costs incurred by anesthesiology groups because of operating rooms not being allocated and cases not being scheduled to maximize operating room efficiency. Anesth Analg 2003; 96:1109–13

13. Karvonen S, Rämö J, Leijala M, Holmström J: Productivity improvement in heart surgery: A case study on care process development. Production Planning Control 2004; 15:238–46

Appendix: Form Used for Recording the Operating Room Times

Date:	OR No./Case No.	Patient ID
Procedure:		
	Time:	Comments:
Patient called for:		
Patient in holding area:		
Patient in induction room:		
Anesthesiologist called for:		
Anesthesiologist available:		
Patient in room:		
Anesthesia ready:		
Surgeon called for:		
Surgeon available:		
Preparation completed:		
Surgery start time:		Incision
Surgery finish:		Closure finished
Dressings and casts completed:		
Anesthesiologist called for:		
Start of emergence:		
Patient out of room:		
Room cleanup start:		
Room cleanup finished:		
Other comments:		